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Ultra-Thick Gate Oxides: Charge Generation and Its Impact on Reliability

Udo Schwalke, Martin Pölzl, Thomas Sekinger, Martin Kerber

Infineon Technologies AG, 81730 Munich, Germany

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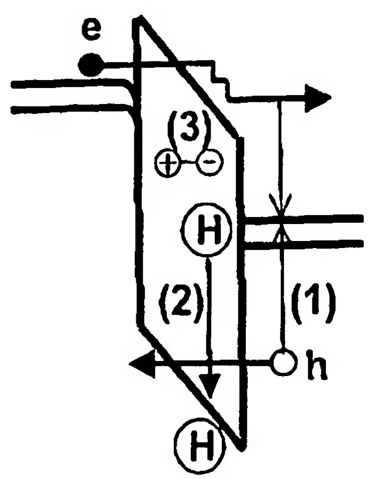
Outline

- **Introduction & Motivation**
- **Electrical Results**
  - I-V characteristics of ultra-thick gate oxides
  - Charge generation & trapping
  - Current transients: Effect of temperature & thickness
- **Discussion on Mechanism**
- **Interpretation of TDDB**
  - Weibull slope & voltage acceleration factor
- **Conclusion**

Introduction: Established TDDB Models



Tox: 5-25nm

1/E Model

(1) Anode hole injection model

(2) Hydrogen release model

$$t_{use} = C \cdot \left| \frac{t_{str}}{C} \right|^{E_{str}/E_{use}}$$

Linear E-Model

(3) Dipole related thermo-chemical model

$$t_{use} = t_{stress} \cdot \exp\left[\gamma \cdot \left(\left|E_{stress}\right| - \left|E_{use}\right|\right)\right]$$

Motivation

- MOS-based high-voltage power devices & HV-ICs rely on ultra-thick gate oxides (UTGOX): Tox: 50-150nm
- Stringent reliability requirements for power-MOS applications accurate lifetime predictions required
- However, present understanding of TDDB mechanisms in UTGOX not satisfying
- Established thin gate oxide (5-25nm) breakdown models (1/E or E) not appropriate for UTGOX:

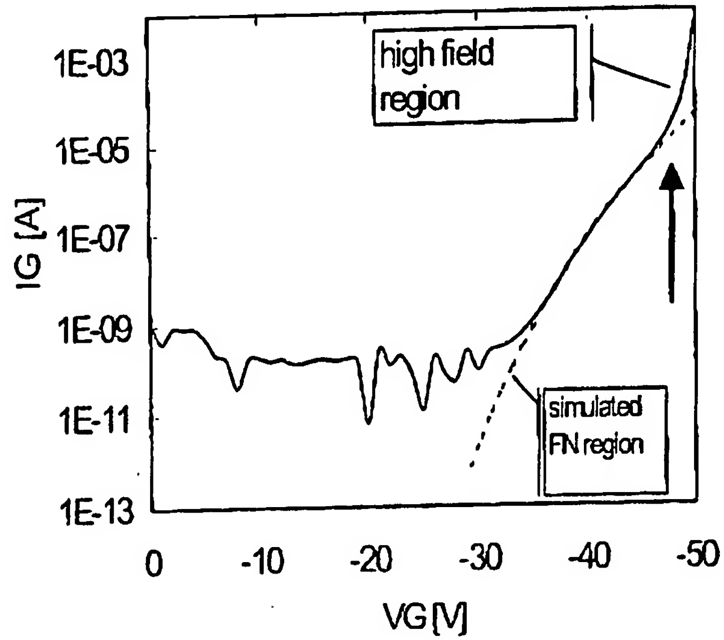
  1. Abnormal voltage acceleration factors
  2. Weibull slope strongly depends on stress voltage

Lifetime predictions for UTGOX questionable

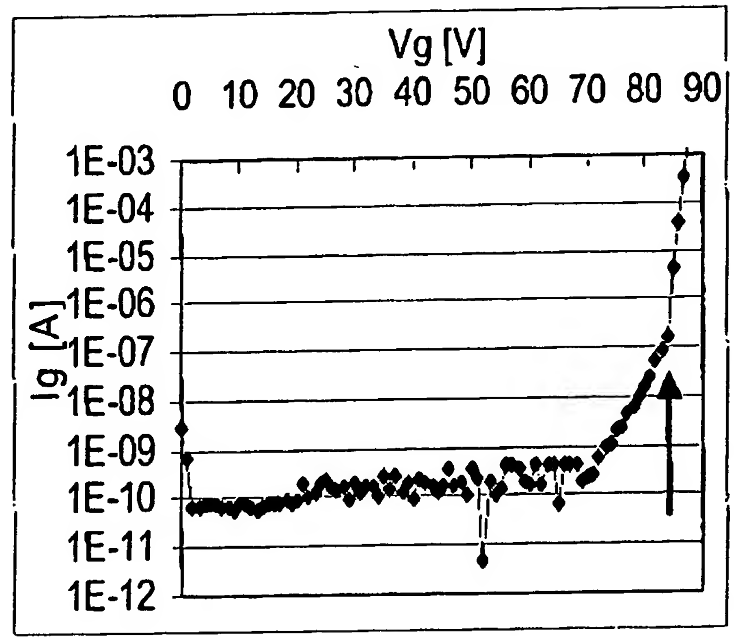
Study on breakdown mechanisms in UTGOX needed

Results: I-V Characteristics of UTGOX

Tox = 55 nm

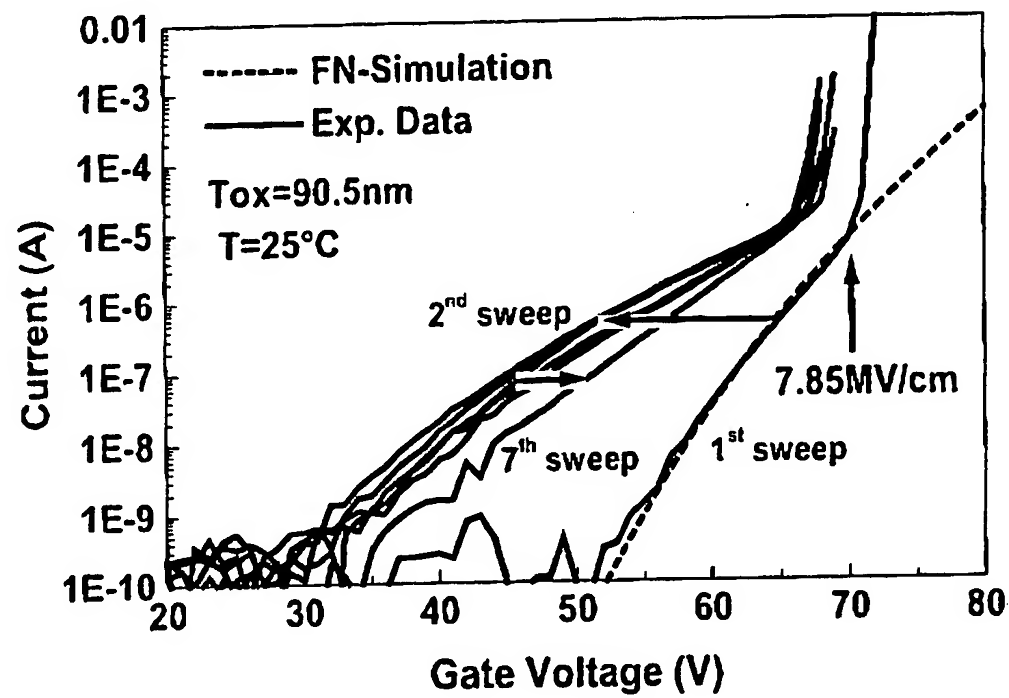


Tox = 120 nm



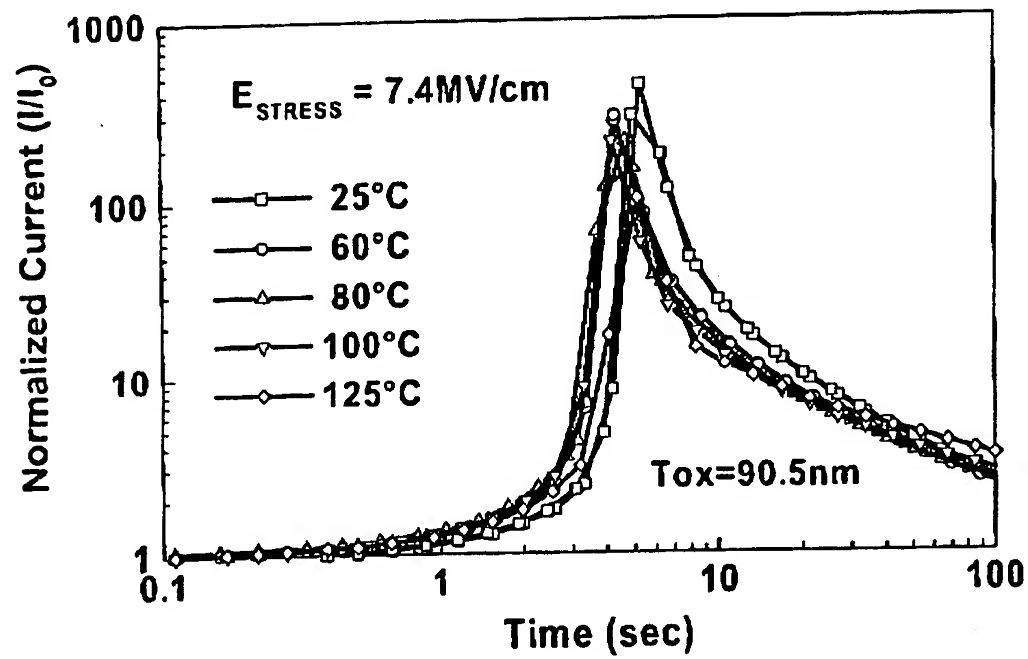
- UTGOX show enhanced conduction mode at higher fields. Dielectric breakdown?
- Independent of stress polarity

Charge Generation & Trapping



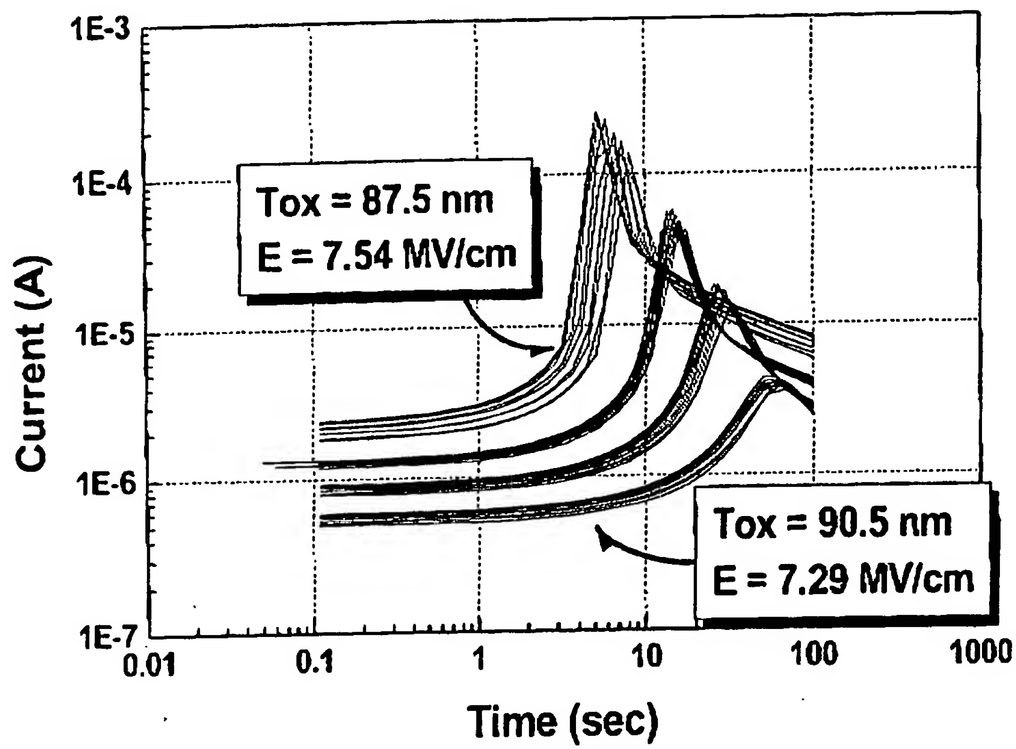
- Steep current increase: No breakdown
- Reversible mechanism & severe charge trapping
- What is the origin of the reversible high oxide conduction?

Current Transients: Effect of Temperature



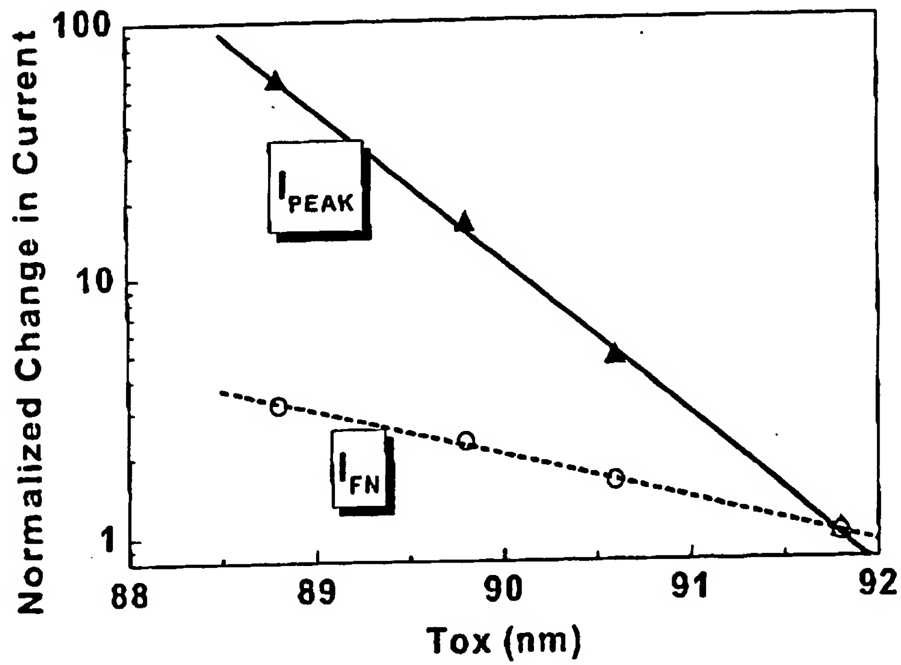
- Current transients not thermally activated
  not thermally activated ohmic conduction
  not related to Poole-Frenkel type mechanism

Current Transients: Effect of Thickness



- Strong dependence on oxide thickness variations & small changes in electric field

Current Transients: Correlation with FN



- Excessive charge generation not due to FN

Discussion on Mechanism

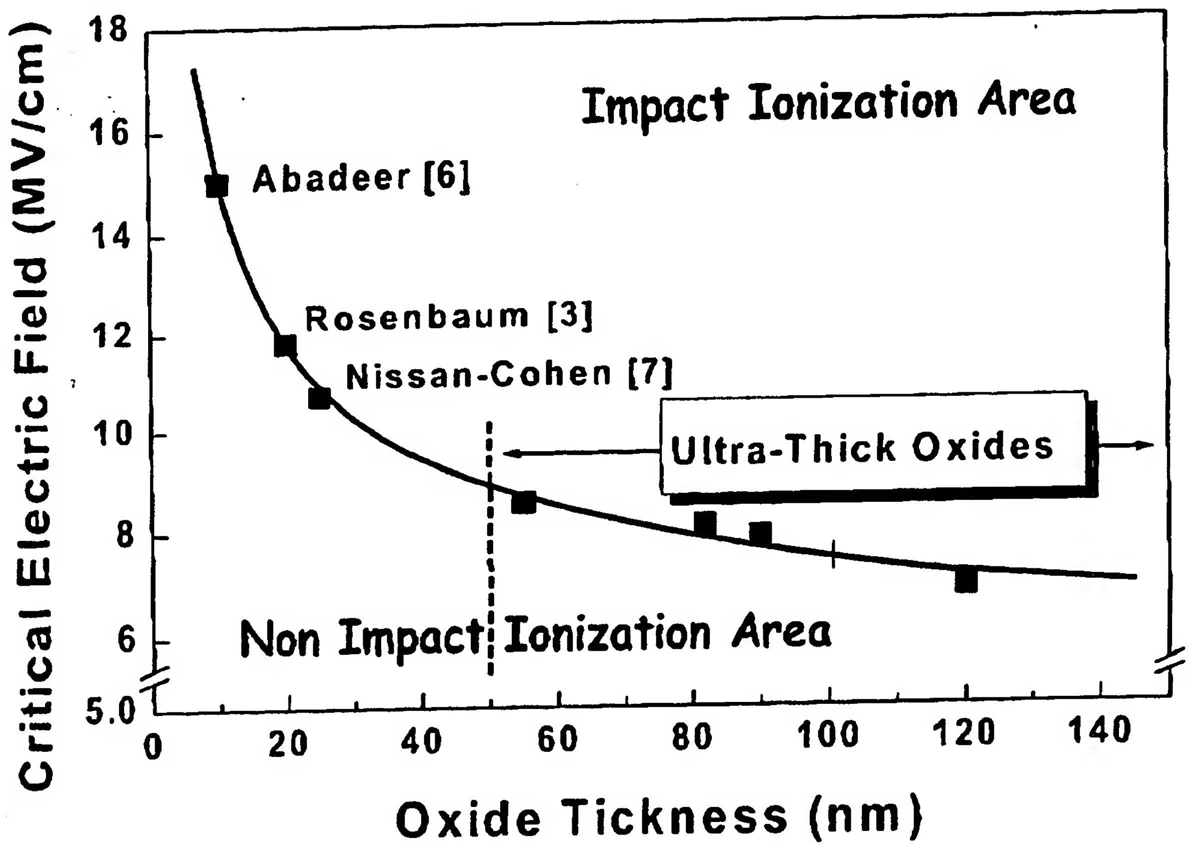
- Electrical results suggest very efficient charge generation mechanism in UTGOX other than via Fowler-Nordheim
- No evidence for thermally activated process
- However, extreme sensitivity on electric field & oxide thickness variation

Suggested mechanism for UTGOX:

Impact ionization (II) + electron-hole pair generation

Critical Field for Impact Ionization

→ kritisches Feld für 200nm ≈ 6 MV/cm !
⇒ bei dieser Feldstärke beginnt die Zerstörung des Oxids
für hohe Zuverlässigkeit im Betrieb werden ca. 3MV/cm zugelassen !
⇒ d.h. für 100V sind wenigstens $d_{ox} > 300nm$ erforderlich



- Critical field for II depends on Tox
- UTGOX: II dominates already at low E (≈ 8MV/cm)

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